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DETERMINATION OF INVISIBLE GOLD WITHIN SULPHIDE MINERALS IN FLOTATION TAILINGS FROM TROUT LAKE MINE, MANITOBA

S.L. Chryssoulis
Process Mineralogy, Surface Science Western

W. Petruk
Mineral Processing Laboratory

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MICROMEDIA

DETERMINATION OF INVISIBLE GOLD WITHIN SULPHIDE MINERALS IN FLOTATION TAILINGS FROM TROUT LAKE MINE, MANITOBA

FOR: HUDSON BAY MINING AND SMELTING COMPANY LTD.
Box 1500
Flin Flon, Manitoba R8A 1N9

Attention: Mr. B. Barlin, Assistant general manager of metallurgy and services
Mr. N.C. McEachern, Supervisor Process Technology

and CANMET
Mineralogy Section
555 Booth Street
Ottawa, Ontario K1A 0G1

Attention: Dr. W. Petruk

SSW/PM/88/11

S.L CHRYSSOULIS
N.J.COOK
Process Mineralogy
Surface Science Western

DETERMINATION OF INVISIBLE GOLD WITHIN SULPHIDE MINERALS IN FLOTATION TAILINGS FROM TROUT LAKE MINE, MANITOBA

S.L. Chryssoulis and W. Petruk

ABSTRACT

Invisible gold has been determined to be present within both pyrite and arsenopyrite. The average gold concentration in pyrite is 0.72 ± 0.38 g/t, and accounts for 26.7 ± 14.8 % of the total gold in the tailings. The average concentration of invisible gold in arsenopyrite is 30.2 ± 8.6 g/t. Arsenopyrite is a minor component of the tailings (0.199 ± 0.035% by volume), and the invisible gold in arsenopyrite accounts for 8.9 ± 3.0% of the total gold in the tailings. Direct cyanidation of the tailings gave a gold recovery of 64.4%. Thus the total gold accounted for in the Trout Lake tailings is 100 ± 8.9%.

KEYWORDS: invisible gold, pyrite, arsenopyrite, SIMS, Trout Lake

TABLE 1

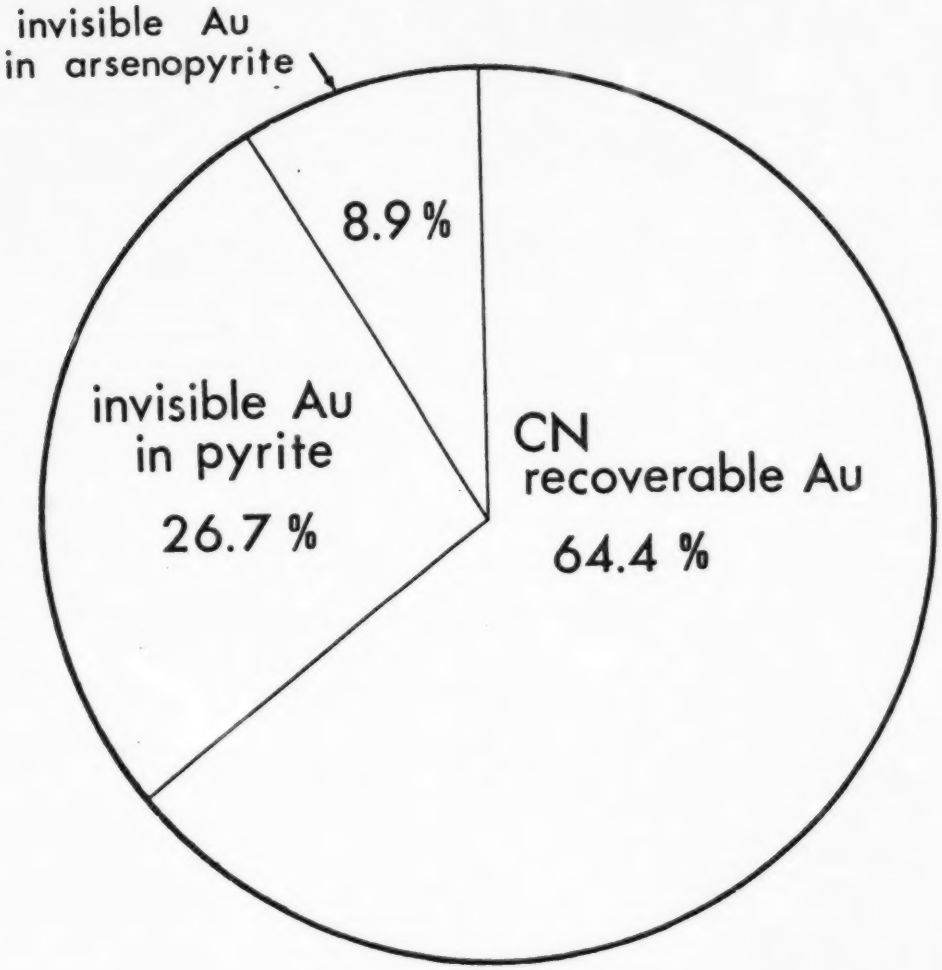
MINERALOGICAL DISTRIBUTION OF GOLD IN FLOTATION TAILINGS

	Assay	Distribution %	Precision
Assayed Au	0.675 + 0.088	100.0	± 13.0
CN- recoverable Au (K_{80} = 18 μm)	0.435 ± 0.030	64.4	± 4.4
Invisible gold in arsenopyrite (concn. 30.2 ± 8.6 ppm) (0.199 ± 0.040 % by mode)	0.06 ± 0.02	8.9	± 3.1
Invisible gold in pyrite (concn. 0.72 ± 0.38 ppm) (24.7 ± 2.2 % by mode)	0.18 ± 0.10	26.7	± 14.8
TOTAL	0.675 ± 0.06	100.0	± 8.9

FIGURE 1

MINERALOGICAL DISTRIBUTION OF GOLD

(Trout Lake, final tailings)



LIST OF CONTENTS

1.0 Introduction

2.0 Methodology

3.0 Results
3.1 Chemical assays
3.2 Mineralogy
3.3 Invisible gold
3.4 Cyanidation tests

4.0 Discussion

5.0 Conclusions

6.0 References

LIST OF TABLES

Table 1 Mineralogical distribution of gold in flotation tailings

Table 2 Chemical assays

Table 3 Cyanidation tests

LIST OF FIGURES

Figure 1 Mineralogical distribution of gold

Figure 2 Distribution of invisible gold in arsenopyrite

Figure 3 Distribution of invisible gold in pyrite

Figure 4 Distribution of arsenic in pyrite

LIST OF PLATES

Plate 1 Sphalerite - arsenopyrite intergrowths

APPENDICES

A1 Initial correspondence

A2 Ion probe microanalytical data

A3 Assays and distribution of invisible gold in heavy and light fractions

OBJECTIVES

1. Determine the gold concentration in the pyrite and arsenopyrite.
2. Obtain the gold mineralogical distribution in the flotation tailings.
3. Determine the arsenic concentration in the pyrite by ion probe microanalysis.

1.0 INTRODUCTION

Flotation tailings from Trout Lake were supplied by N.C. McEachern, Supervisor in Process Technology with Hudson Bay Mining and Smelting Co. Ltd., for determination of the distribution of gold. It was suspected that part of the gold in the sample was "invisible", i.e. present in solid solution within the crystal lattice of the sulphide minerals.

Gold contents of the deposit are low (head grade 1.25 g / tonne). Sixty percent of the gold is recovered in the Cu-concentrate. A further 7% is recovered in the Zn-concentrate. A total of 33 % of the gold reports to the tailings, which have a sulphide content of about 20 %, mostly pyrite.

Previous mineralogical studies[1] have shown that the only gold mineral present is mercurian electrum. The electrum was most commonly present associated with chalcopyrite and as inclusions within, and in fractures between, pyrite grains. No association of Au with As was noted, either geochemically or paragenetically.

In previous testing (Appendix A1), direct cyanidation of the tailings gave a Au recovery of only 35%, which could be increased to 44 % by regrinding. Production of a pyrite concentrate by flotation gave a 72 % Au recovery. Direct cyanidation of this concentrate gave a recovery of only 40 % of the gold, leading to the conclusion that invisible gold in pyrite represented a significant portion of the total gold.

2.0 METHODOLOGY

A sample of Trout Lake circuit tailings was received from HBM. The sample was sieved into the size fractions -53 µm, 53-90 µm, and + 90 µm. The + 90 µm fraction (11.5 % of the total sample) was separated using heavy liquid techniques. The heavy fraction represented 21 % of the total + 90 µm fraction. Nine one inch polished grain mounts were prepared from the heavy +90 µm fraction for ion probe microanalysis.

Optical microscopy was used to determine the gold minerals size and association. The invisible gold in the sulphide minerals was determined by ion probe microanalysis (2). The arsenic concentration in pyrite was determined by ion probe microanalysis.

3.0 RESULTS

3.1 CHEMICAL ASSAYS

A series of chemical assays were determined on the bulk tailings sample. Results are given in Table 2.

3.2 MINERALOGY

The following minerals were identified in the sample:

Pyrite, sphalerite, chalcopyrite, arsenopyrite, galena, cassiterite, native antimony.

Pyrite: The pyrite grains are generally fresh and clean in appearance. Inclusions of silicates and of other sulphides (chalcopyrite, pyrrhotite and sphalerite) are widespread. Intergrowths of pyrite with other grains are rare.

Arsenopyrite: is present intergrown with pyrite and also forms fine grained intergrowths with sphalerite (Plate 1). Sphalerite-arsenopyrite composite grains had been previously noted (1) within the massive sphalerite and banded pyrite - sphalerite ore types.

Other minerals: Sphalerite contains chalcopyrite disease (inclusions of chalcopyrite), and is commonly intergrown with chalcopyrite and pyrrhotite. Trace galena and native antimony are noted.

Gold minerals: No grains of native gold or electrum were recognised in the investigated samples.

3.3 INVISIBLE GOLD

Invisible gold is the gold which is invisible under the optical or scanning electron microscopes. It may either be in the crystal lattice of the sulphide minerals or fine, sub-micron scale inclusions of native gold or electrum (<0.1 μm). The invisible gold is not recoverable by direct cyanidation, and requires prior oxidation of the host sulphides in order

TABLE 2

CHEMICAL ASSAYS

Au	:	0.60	
		0.60	
		0.73	
		0.77	
x + λ	:	0.675 ± 0.10	g/t
Au (HBM):	=	0.63	g/t

S:		13.2	%
	±	1.2	
Te:	<	3	ppm
Bi:	<	20	ppm
Sb:	<	20	ppm
As:		1040 ± 120	ppm
C (organic):	<	0.05	%

Plate 1 Fine-grained arsenopyrite combined with sphalerite.

for the gold to be recovered. Invisible gold was found to be present in both pyrite and arsenopyrite. Concentrations in the arsenopyrite are 40 times higher than in the pyrite.

The average concentration of the gold in 44 arsenopyrite particles, as determined with the ion microprobe was 30.2 parts per million (g/t). with a confidence interval of 8.6 g/t, at a 95% significance level. This means that 95 out of 100 arsenopyrite particles would have a gold concentration in the range from 21.6 to 38.8 g/t. Measured concentrations in the sampled population ranged from 2 to 112 g/t. The distribution of invisible gold is shown as a histogram in Figure 2.

The average concentration of the gold in 46 pyrite particles, as determined with the ion microprobe was 0.72 parts per million (g/t), with a confidence interval of 0.38 g/t, at a 95 % significance level. Measured concentrations in the sampled population ranged from 0 to 6.80 g/t. The distribution of invisible gold in pyrite is shown as a histogram in Figure 3.

The arsenic contents of the pyrite grains were also measured (Figure 4). The average As content of pyrite in the 47 pyrite particles was 500 $\pm$ 247 ppm. The measured analyses ranged from less than 10 ppm to 4100 ppm (0.41%). There was no correlation between the As and Au content of pyrite in these As-poor pyrites. A positive correlation has been observed in arsenian pyrites from other ores.

The ion probe microanalysis data is presented in Appendix A2.

3.4 CYANIDATION TESTS

Three cyanidation tests at progessively finer grinds (K_{80} 50 µm; 23 µm; 18 µm) were carried out in order to determine the amount of gold recoverable by direct cyanidation and to obtain an idea of its size distribution. Exposed native gold and electrum are amenable to cyanidation, however, sub-micron gold and gold in solid solution in the pyrite and arsenopyrite are not recoverable. Conditions were: 33% solids, 1 g/l NaCN, pH 10.5 - 11.0, 48 hours. Increasing the fineness of grind increased Au recovery from 57% at K_{80} = 50 µm to 64.4% at K_{80} = 18 µm. Results are given in Table 3.

FIGURE 2

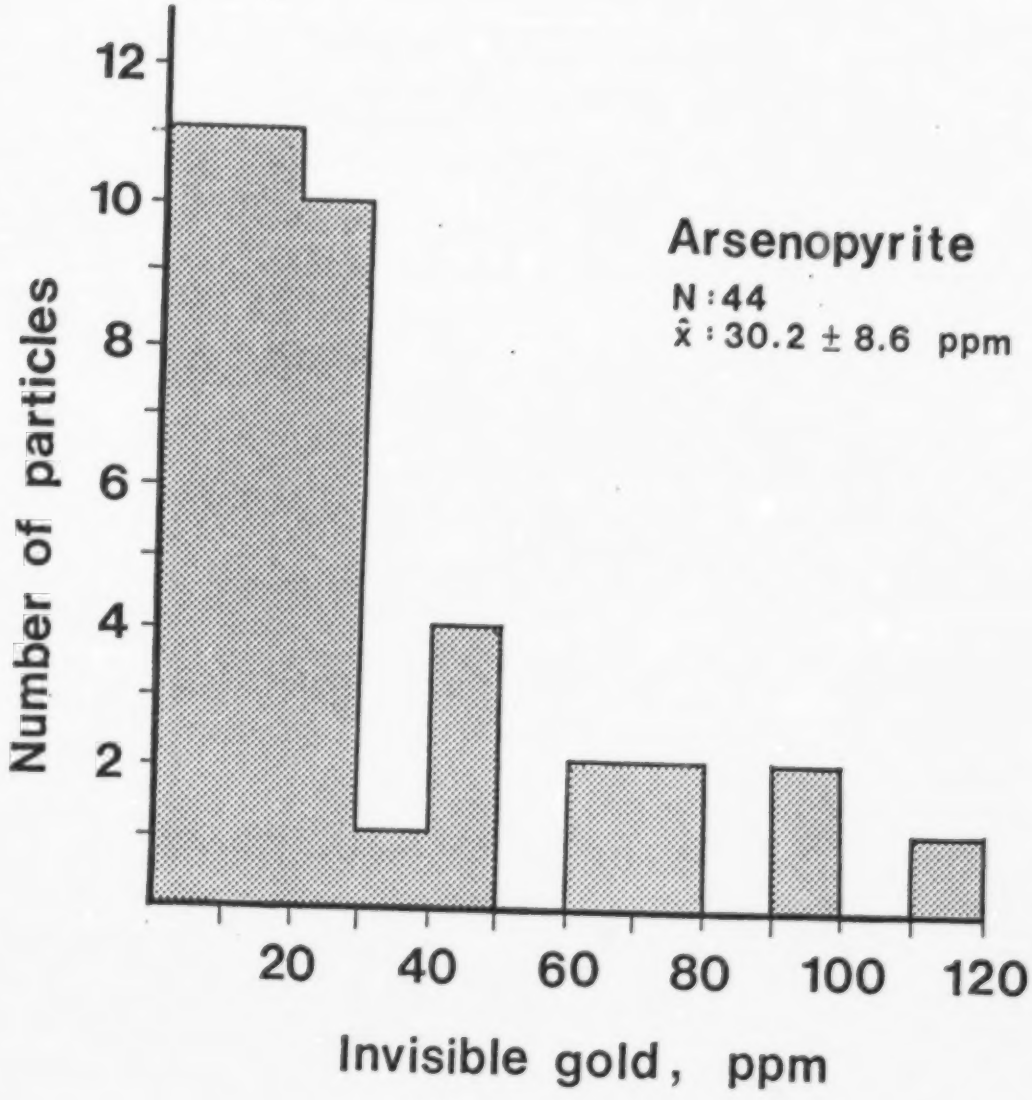

12
10
8
6
4
2
Number of particles
Arsenopyrite
N : 44
x̄ : 30.2 ± 8.6 ppm
20
40
60
80
100
120
Invisible gold, ppm

FIGURE 3

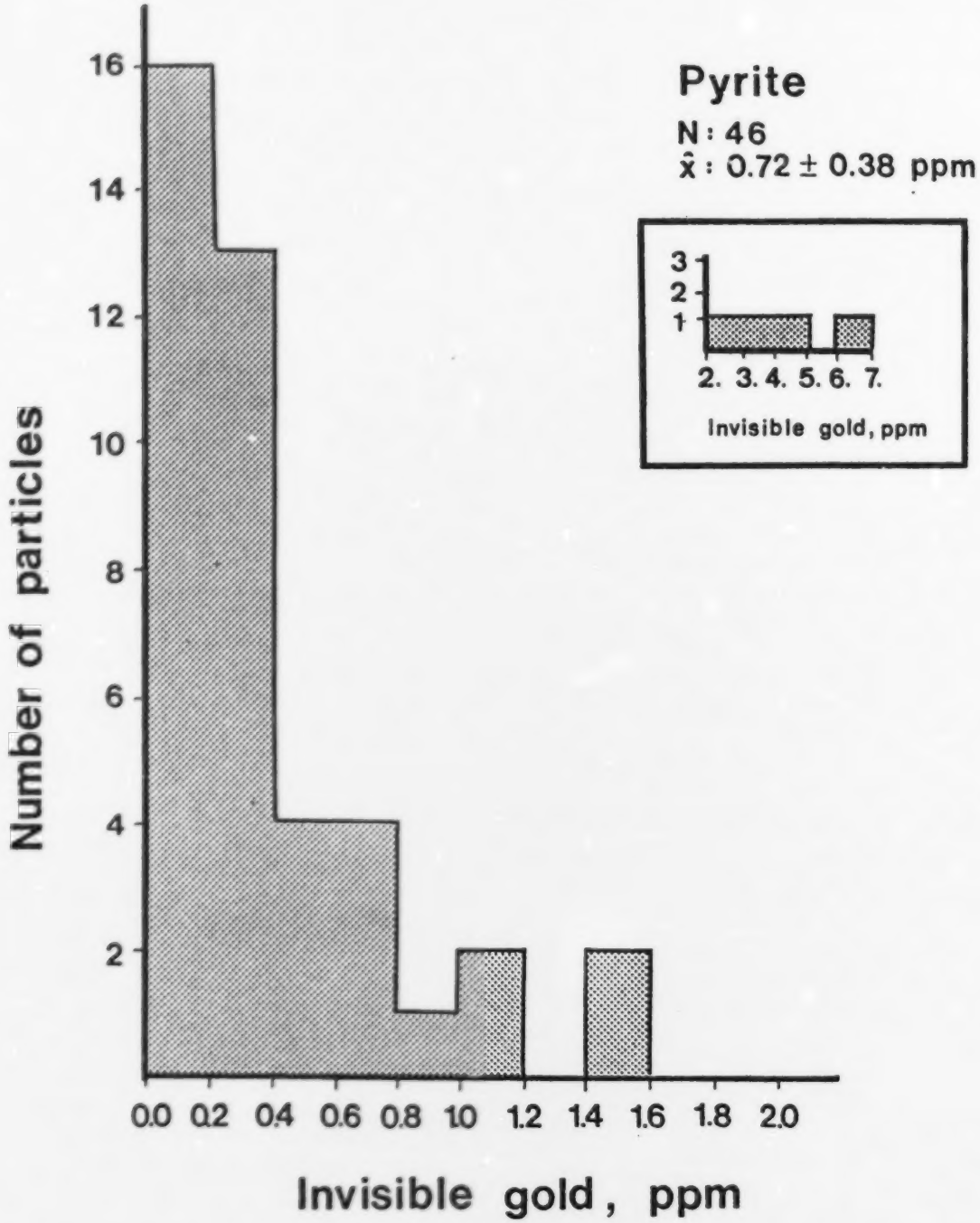

Pyrite
N: 46
x̂: 0.72 ± 0.38 ppm
3
2
1
2. 3. 4. 5. 6. 7.
Invisible gold, ppm
Number of particles
16
14
12
10
8
6
4
2
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Invisible gold, ppm

FIGURE 4

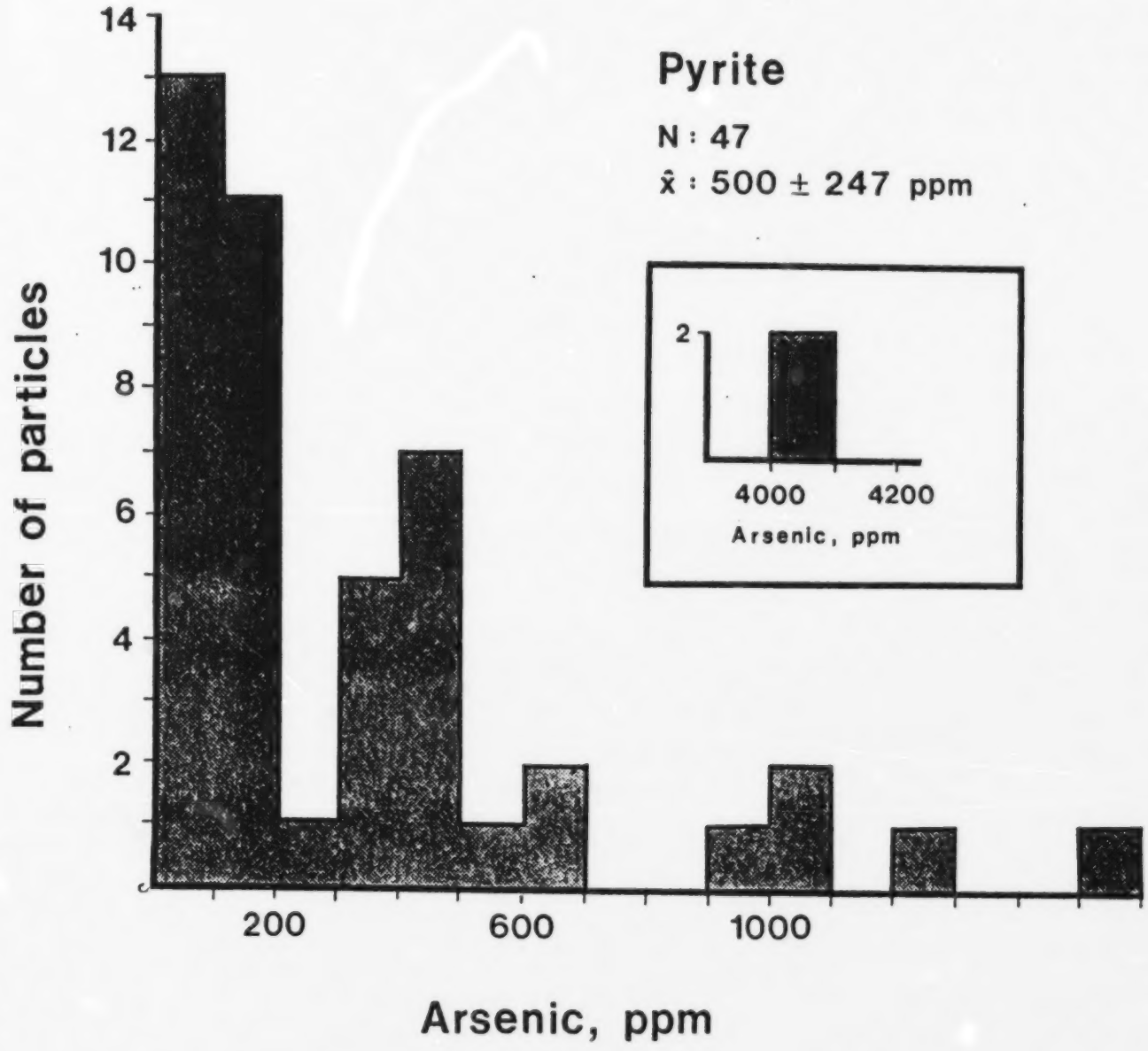

Pyrite
N : 47
x̂ : 500 ± 247 ppm
2
4000
4200
Arsenic, ppm
14
12
10
8
6
4
2
0
Number of particles
200
600
1000
Arsenic, ppm

TABLE 3

CYANIDATION TESTS

Test #	K_{80} (μm)	% Extrn Au	Residue g/t Au	HEAD x Direct g/t	HEAD Calc. g/t	Yield %
1	50	34.9	0.29	0.675	0.45	57
2	23	43.2	0.23	± 0.08	0.40	66
3	18	43.8	0.24		0.43	64.4

$$\text{Yield} = \frac{\text{(Direct head)} - \text{(Residue)}}{\text{(Direct head)}}$$

4.0 DISCUSSION

Cyanidation testing of the tailings showed that at a finest grind of K_{80} = 18 µm, 64.4% of the total gold (0.675 ± 0.088 g/t) could be recovered by direct cyanidation. The difference between the gold recovery at a similar grind (K_{80} = 50 µm) from previous testing, 57% versus 34.5% Au can be explained by the higher cyanide concentration, longer duration of test, and lower pulp density used in the present study. The objective of these cyanide tests was to determine a maximum value for the cyanide recoverable (visible) gold, rather than to evaluate cyanidation for processing the flotation tailings.

The remaining 35.6% of the gold is present in solid solution within the crystal lattices of pyrite and arsenopyrite. In order to calculate the amounts of invisible gold in the two minerals, it is neccessary to know the proportions of pyrite and arsenopyrite in the sample.

The proportion of pyrite can be calculated from the sulphur assay (13.2 ± 1.2%). Since other sulphides account for less than one per cent of the sample, it is reasonable to calculate all sulphides as pyrite. The proportion of pyrite is calculated to be 24.7 ± 2.2 %. The proportion of arsenopyrite may be calculated from the As assay (1040 ± 120 ppm) by subtracting the average As solid solution in pyrite (500 ± 247 ppm) which has been measured with the ion microprobe. Thus the proportion of arsenopyrite is calculated to be 0.199 ± 0.040%.

Knowing the concentration of gold in arsenopyrite to be 30.2 ± 8.6 g/t, it can be shown that 0.06 ± 0.02 g/t, or 8.9 ± 3.1% of the total gold is present within solid solution in arsenopyrite.

The concentration of gold in pyrite is 0.72 ± 0.38 g/t, so it can similarly be calculated that 0.18 ± 0.10 g/t, or 26.7 ± 14.8 % of the total gold can be accounted for within solid solution in pyrite. Thus 100% of the gold can be accounted for, with an error of 8.9%. The mineralogical distribution for gold is given in Table 1 and is presented as a pie diagram in Figure 1. The distribution of gold can also be calculated for the heavy and light fractions (Appendix A3).

5.0 CONCLUSIONS

Pyrite is the principal carrier of invisible gold in the tailings. The average gold concentration of pyrite is 0.72 ± 0.38 g/t. Invisible gold in solid solution within the crystal lattice of pyrite accounts for 26.7 ± 14.8% of the total gold in the tailings.

Arsenopyrite contains significant concentrations of gold. The average concentration was 30.2 ± 8.6 g/t. However, arsenopyrite is only a volumetrically minor constituent of the sample (0.199 ± 0.040 % by volume). The amount of invisible gold in the pyrite is three times greater than the amount in arsenopyrite in the tailings.

This study supports the validity of earlier data, and confirms that approximately one third of the gold in the tailings is invisible, and that two thirds of the gold is recoverable by cyanidation.

6.0 REFERENCES

(1) R.E. Healy
The mineral characteristics that affect metal recoveries from the Cu, Zn, Pb and Ag ores from Mantitoba.
Part 1: An investigation of the ore mineralogy of the Trout Lake deposit, with a view to predicting mineral liberation and metal recovery during ore dressing.
Report; Canada - Manitoba Mineral Development Agreement 1987.

(2) S.L. Chryssoulis, L.J. Cabri and R.S. Salter
Direct determination of invisible gold in refractory sulphide ores.
Proceedings of the International Symposium on Gold Metallurgy, Winnipeg, 1987. p. 235-244.

APPENDIX A2

ION PROBE MICROANALYTICAL DATA

INVISIBLE GOLD CONCENTRATION IN SULPHIDES
(HBM, Trout Lake, Man.)

Arsenopyrite

Particle #	Au, g/t	Particle #	Au, g/t
1	68.	37	3.
2	19.	38	7.8
3	112.	39	10.
4	50.	40	100.
7	17.5	41	6.
8	9.7	42	33.
9	18.6	47	25.
14	26.1	5	2.8
16	3.7	59	28.8
17	80.	63	17.5
18	14.9	66	27.3
19	4.5	67	26.4
20	17.2	70	49.
22	23.	71	42.
23	65.	72	104.
26	9.5	73	16.
28	23.4	80	12.
31	30.	84	26.
31α	18.	85	80.
34	16.	95	11.
35	44.	97	23.
36	6.	100	2.

n = 44

x = 30.2 ± 8.6 g/t Au

Pyrite

Particle #	Au, g/t	Particle #	Au, g/t
6	0.07 < MDL	57	0.52
10	0.02 < MDL	58	3.49
11	3.00	60	0.31 < MDL
12	0.02 < MDL.	61	0.38 < MDL
13	0.00	62	0.28 < MDL
15	1.18	64	0.05 < MDL
21	0.03 < MDL	65	0.00 < MDL
24	0.00	68	0.65
25	0.00	69	0.44 < MDL
27	0.10 < MDL	74	0.00 < MDL
29	0.55	79	0.35
29α	0.34 < MDL	81	0.76
30	0.16 < MDL	83	0.46
31	0.27 < MDL	86	1.52
44	0.28 < MDL	87	1.50
45	0.00 < MDL	88	1.08
46	0.00 < MDL	89	0.98
49	0.00 < MDL	90	0.24
50	0.01 < MDL	91	0.32
51	0.21 < MDL	92	6.80
52	0.22 < MDL	93	0.76
53	0.62	94	0.29
54	4.49	98	0.22

n = 46

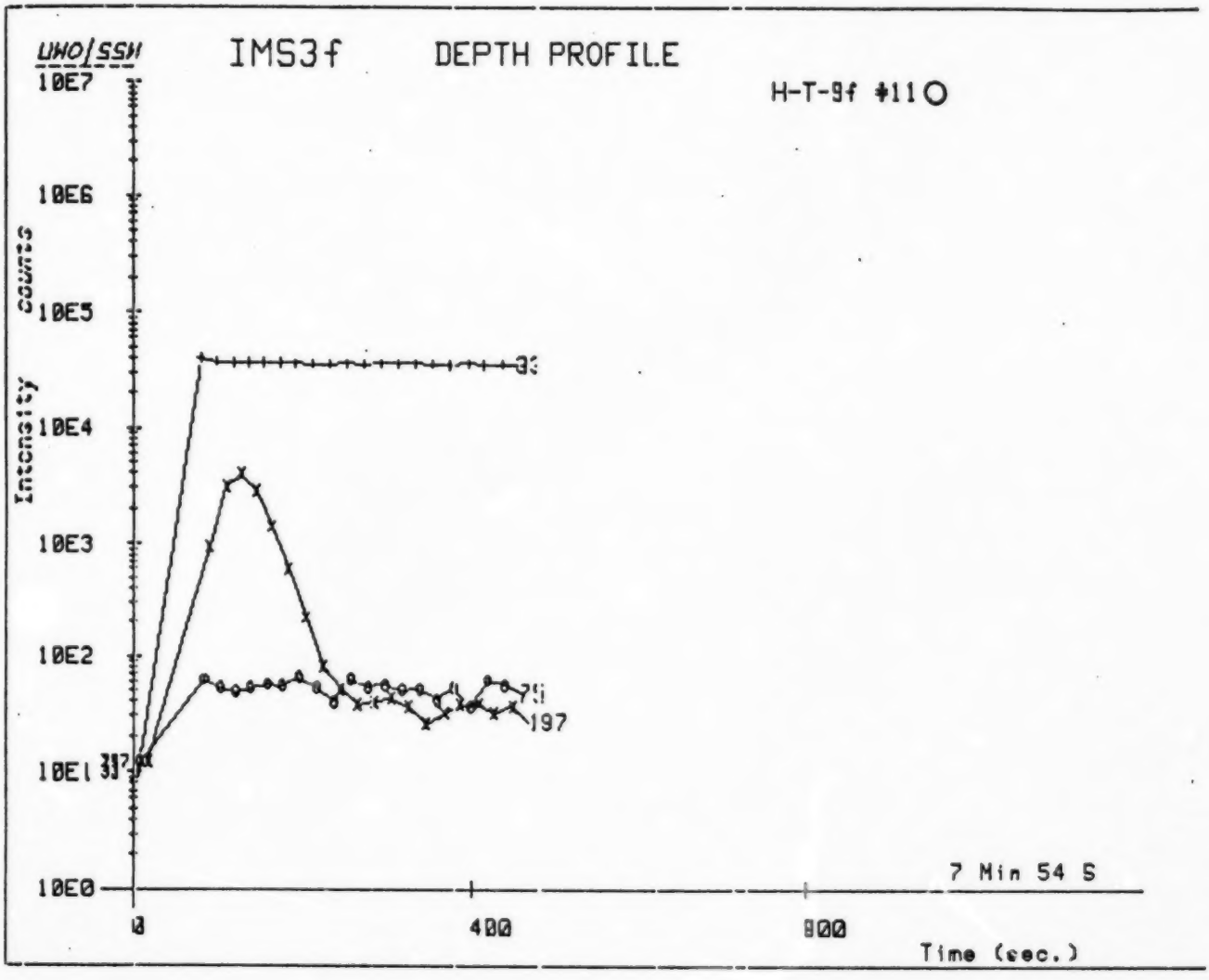
x = 0.72 ± 0.38 g/t Au

Arsenic in pyrite

Particle #	Arsenic (ppm)	Particle #	Arsenic ppm)
6	84	57	14
10	54	58	4100
11	150	60	50
12	54	61	39
13	340	62	1600
15	125	64	145
21	42	65	500
24	640	68	470
25	105	69	72
27	200	74	115
29	570	79	4100
30	490	81	96
33	260	83	< 10
23D	630	86	< 10
30D	500	87	190
44	1000	88	25
45	58	89	420
46	460	90	200
49	110	91	1050
50	350	92	410
51	370	93	1300
52	170	94	320
53	330	98	130
54	1100		

N = 47

$x = 500 \pm 247$ ppm As



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DATE:
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SECONDARY IONS : -
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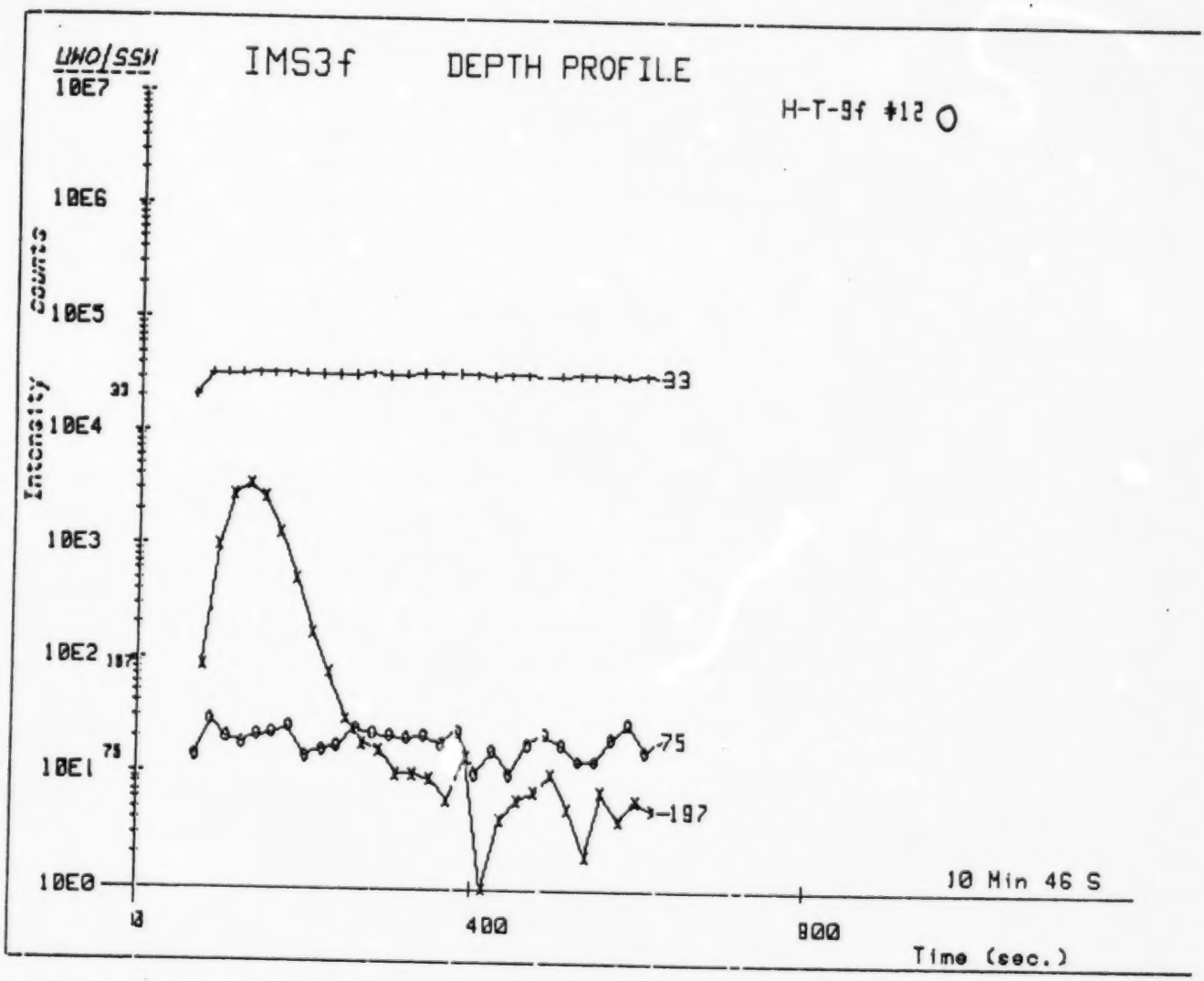
PRIMARY CURRENT : 379 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 5 6



SAMPLE:H-T-9f #12 O
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SECONDARY IONS : -
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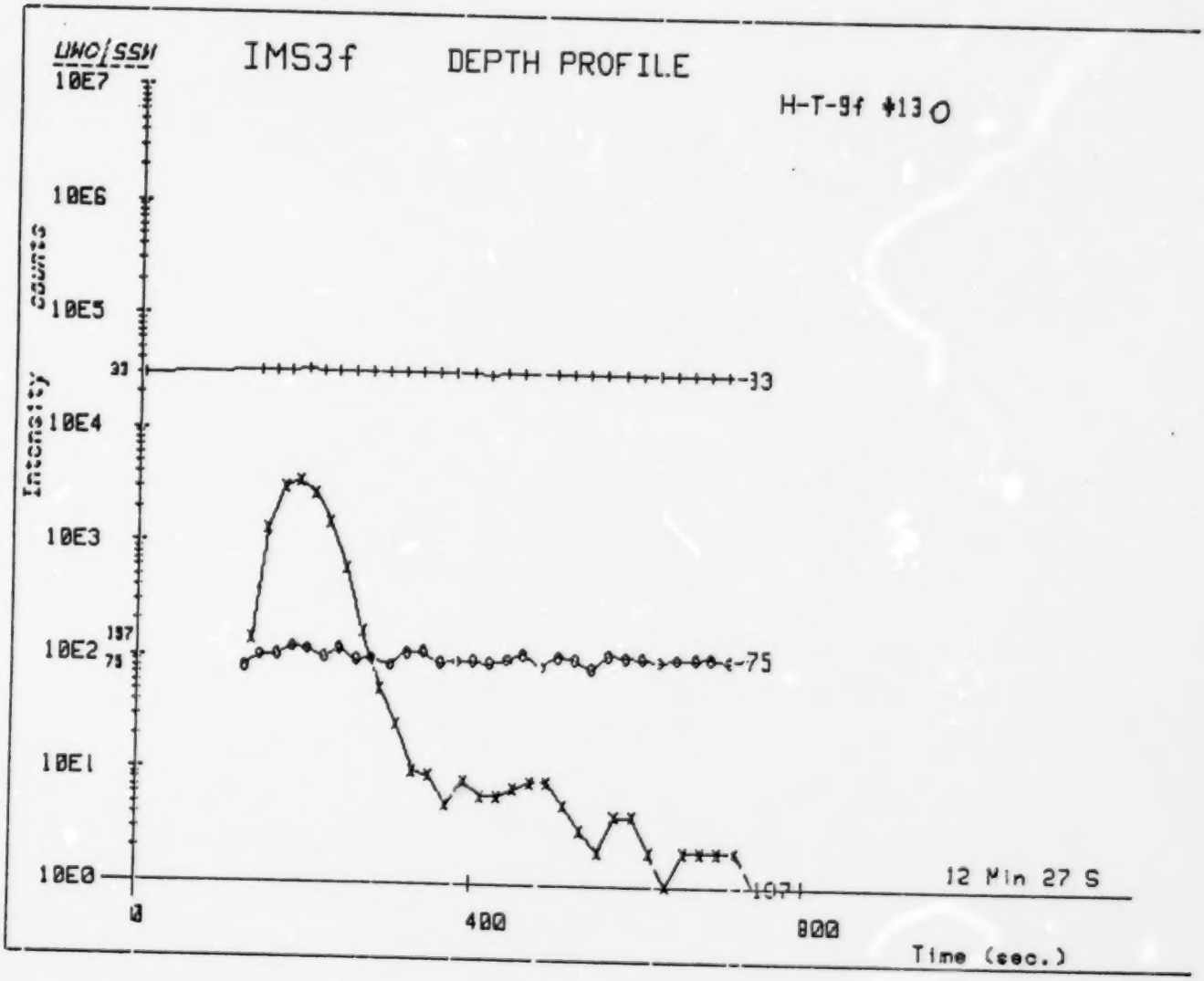
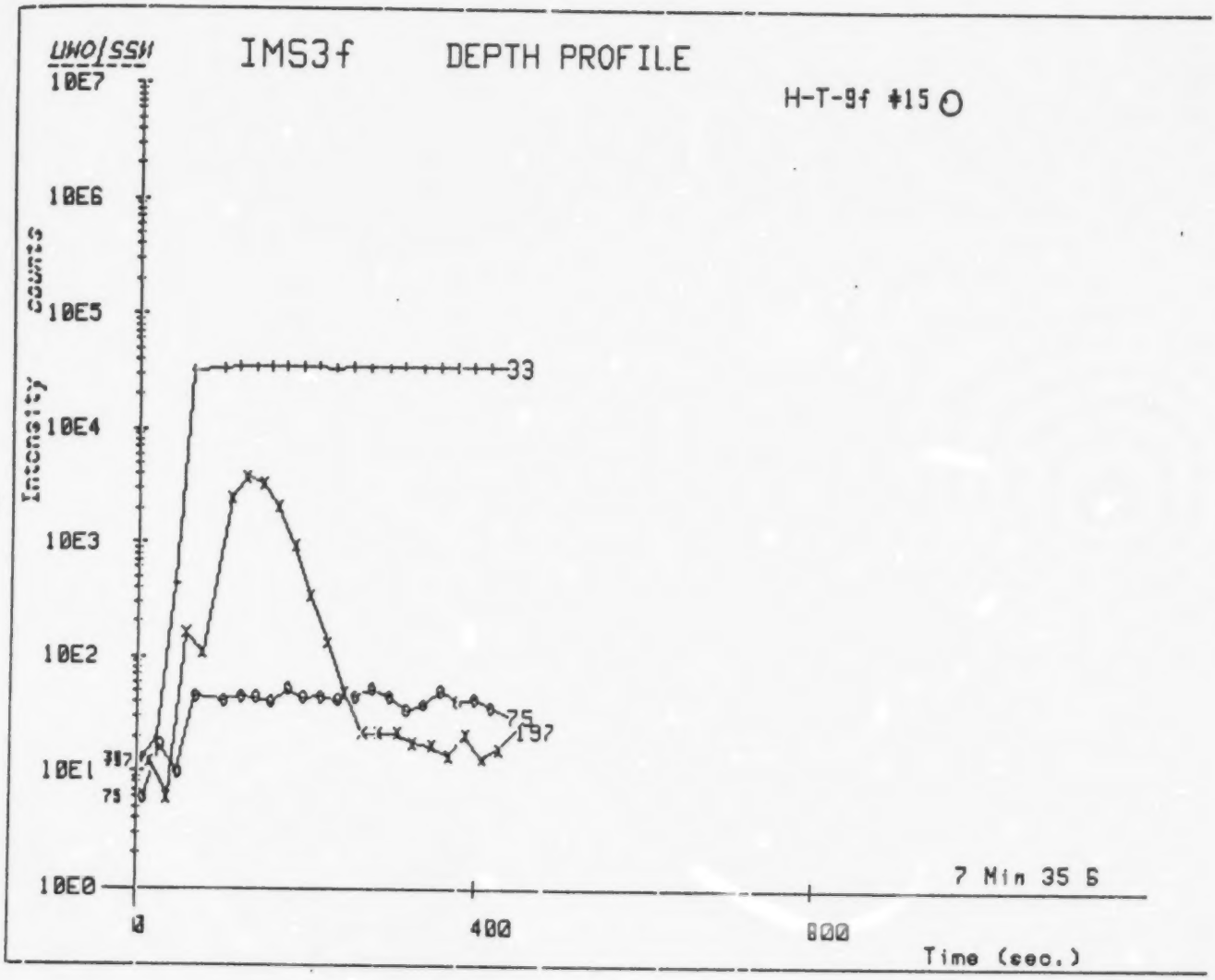
PRIMARY CURRENT : 354 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 5 6



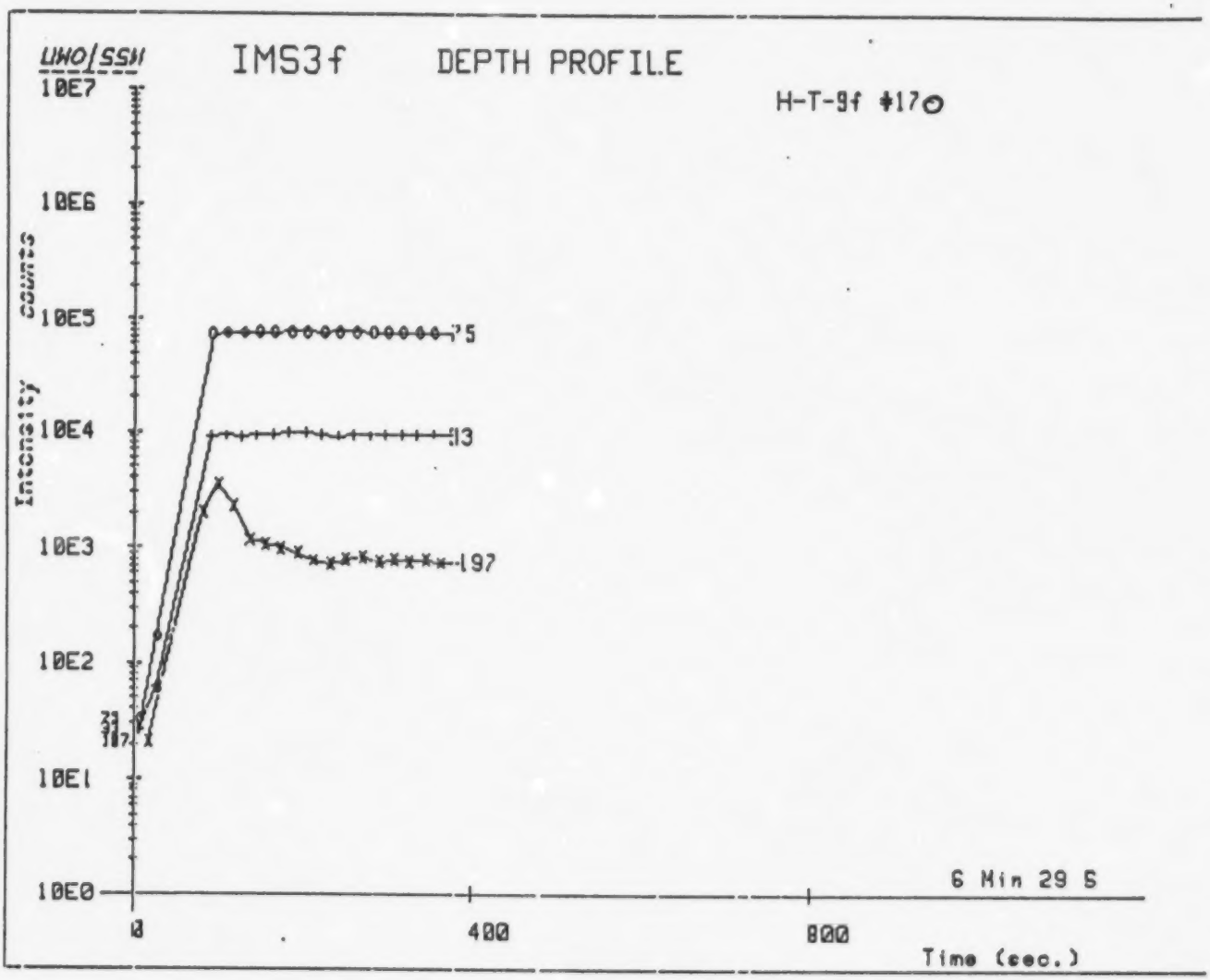
SAMPLE:H-T-9f #13 O
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 350 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 :



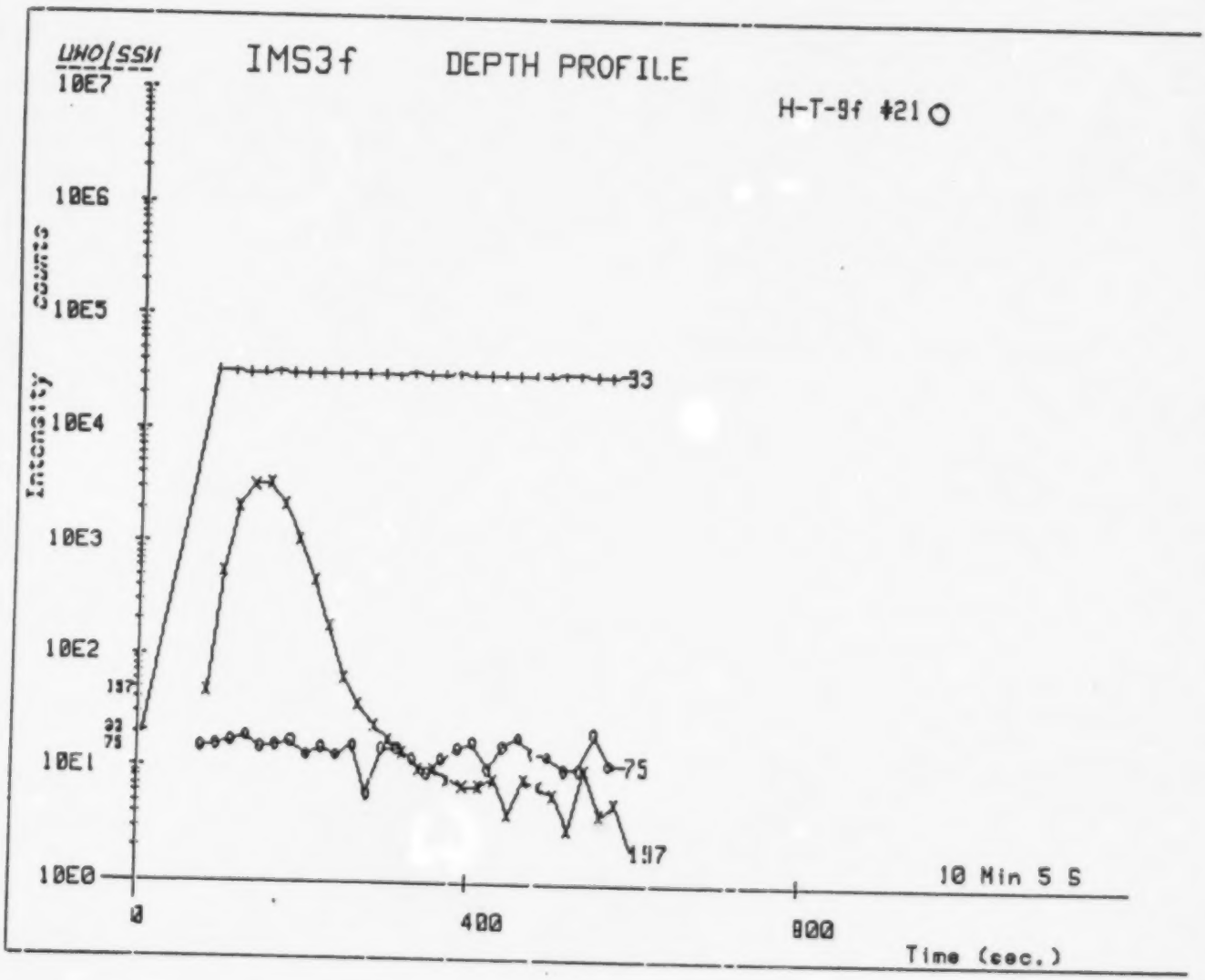
SAMPLE:H-T-9f #15 O
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 343 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 :



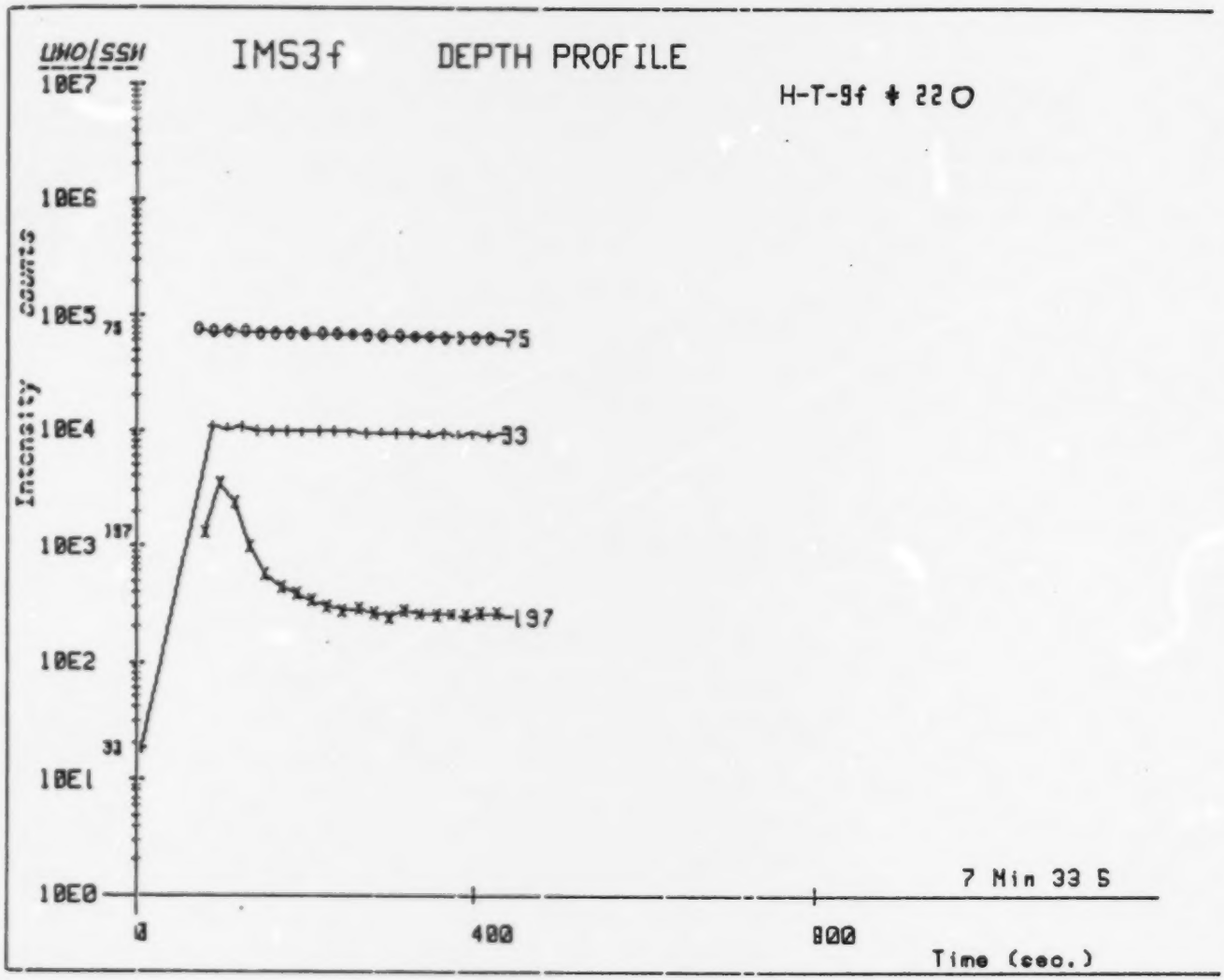
SAMPLE:H-T-9f #17O
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 332 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3



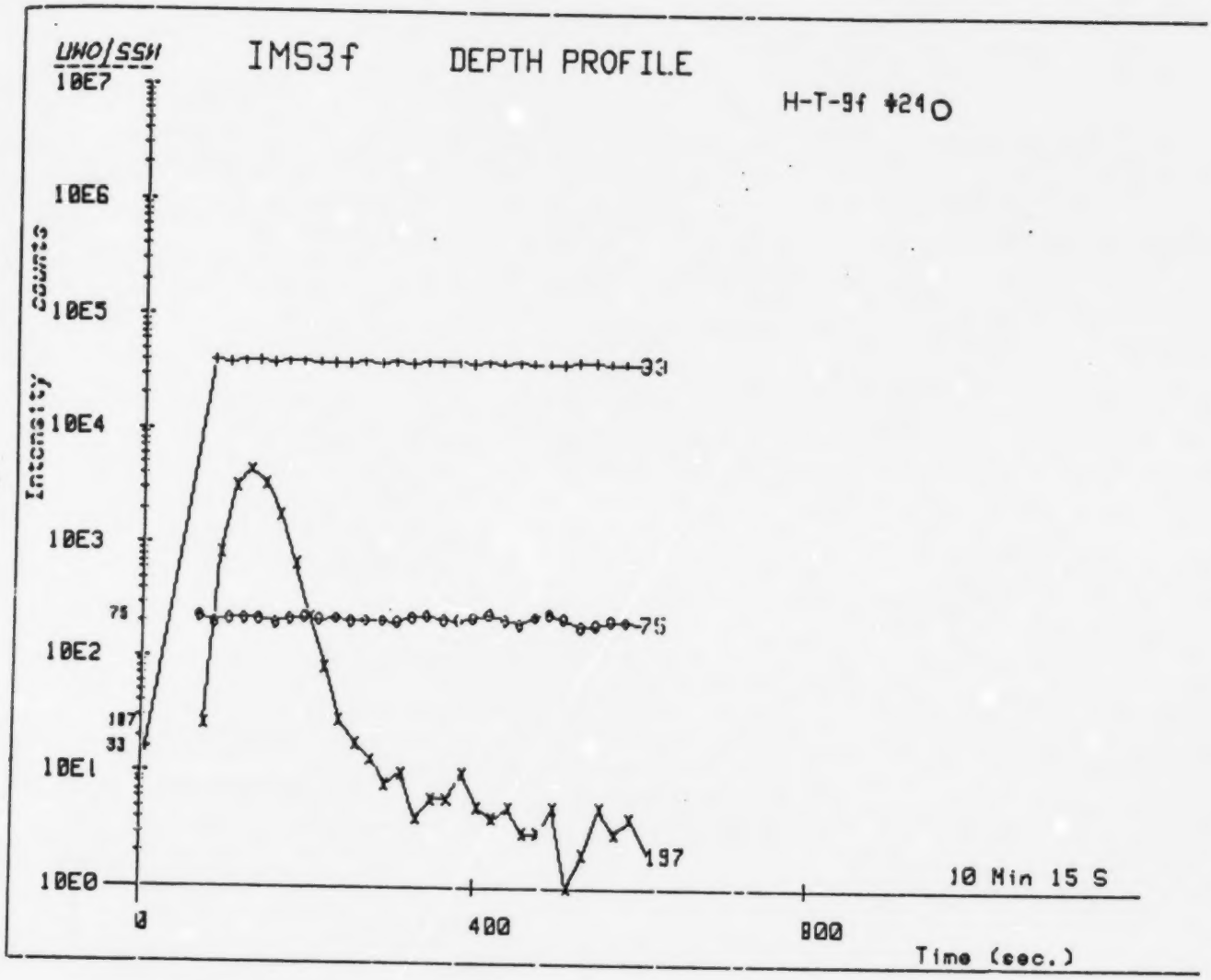
SAMPLE:H-T-9f #21 O
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 325 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS



SAMPLE: H-T-9f # 22 O
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 330 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3



SAMPLE:H-T-9f #24

DATE:

PRIMARY IONS : CS +

SECONDARY IONS : -

DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 387 NANO AMP

HIGH VOLTAGE :

156.65 DD.D

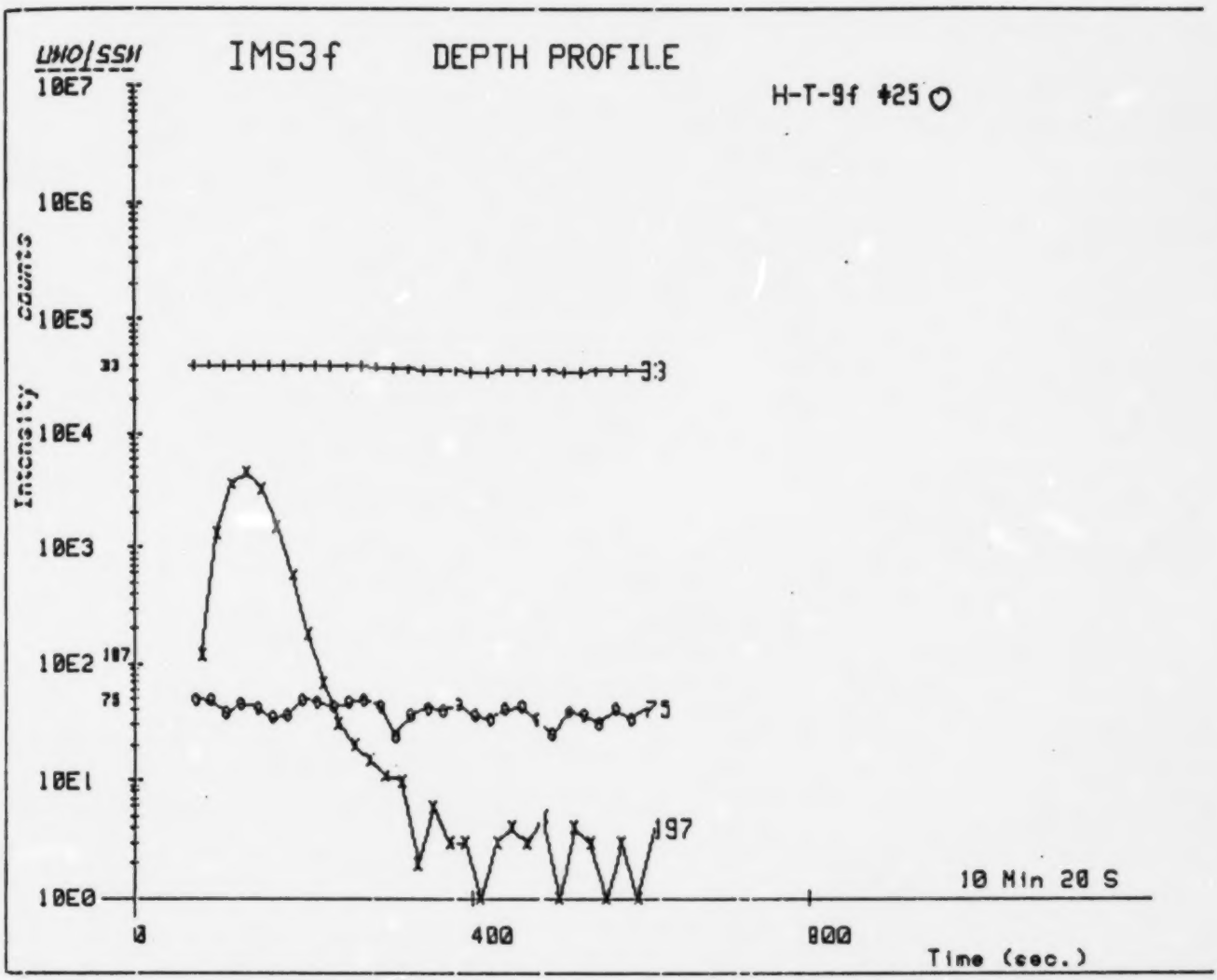
<ILOVOLTS

RASTERING : 250 MICRONS

TRANSFER OPTICS : 150 MICRONS

FIELD APERTURE : 1 2 3

CONTRAST APERTURE : 4 3 2 :



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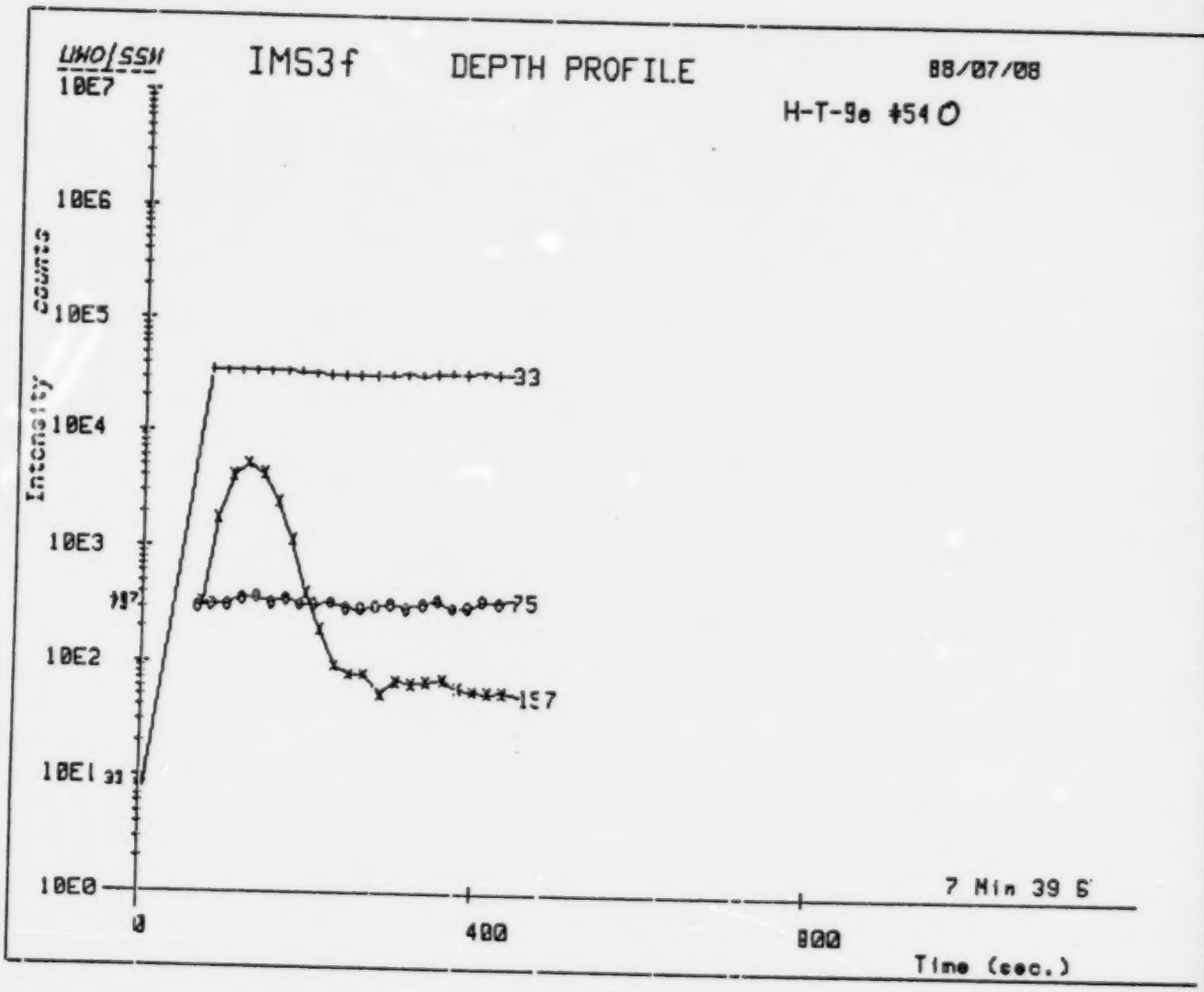
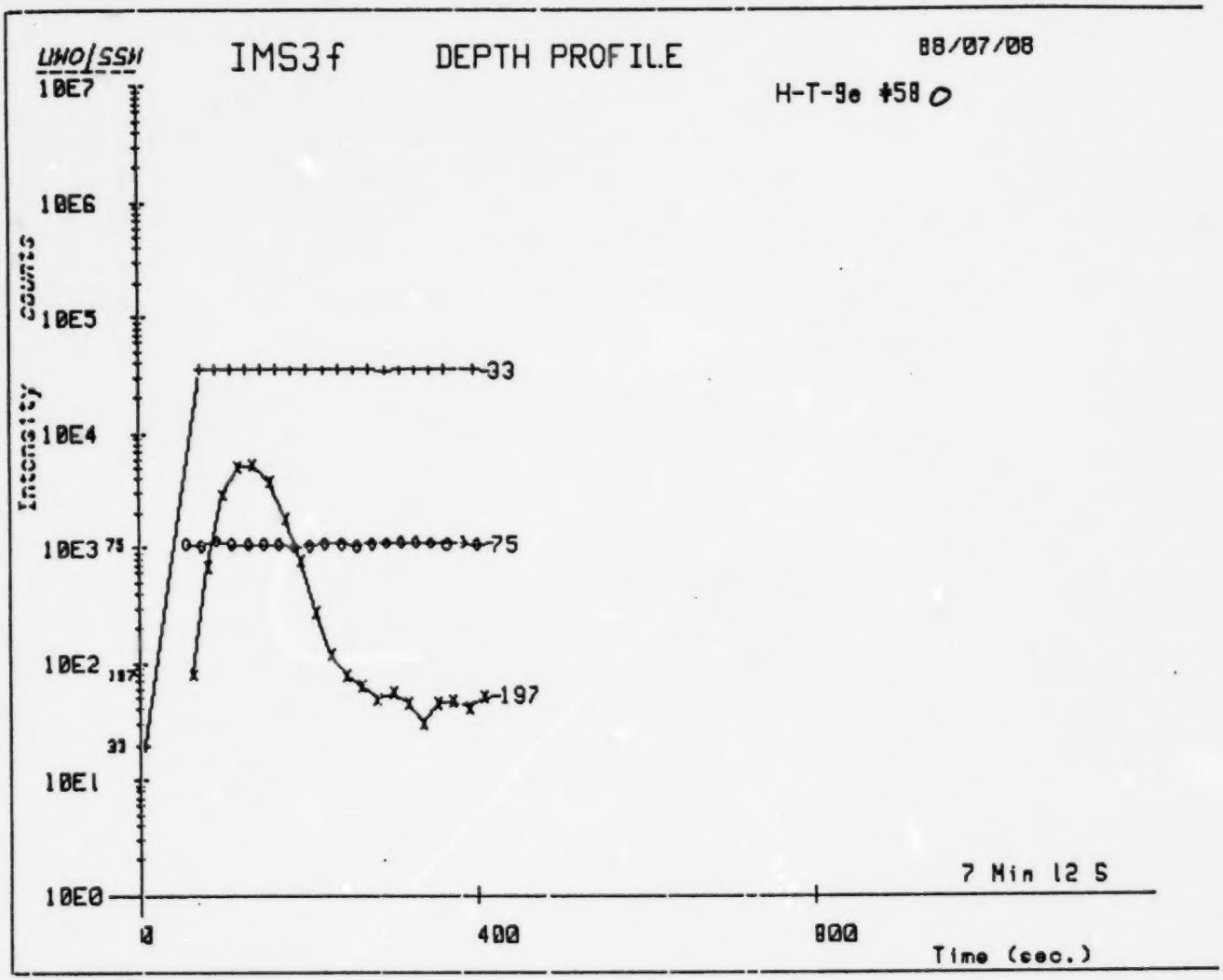
DATE:
PRIMARY IONS : CS +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 388 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3



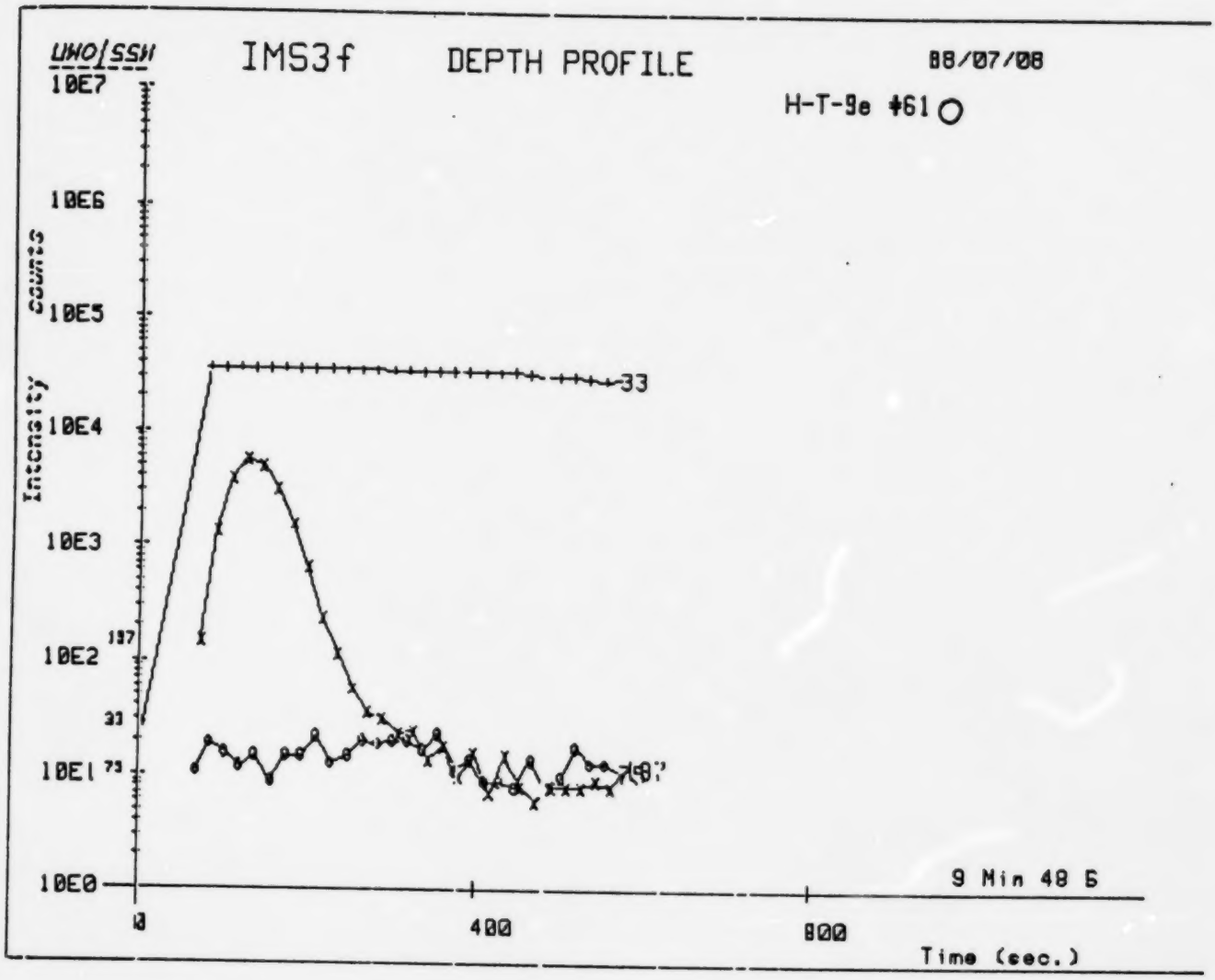
SAMPLE:H-T-9e #54 O
DATE:88/07/08
PRIMARY IONS : CESILM +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 375 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3



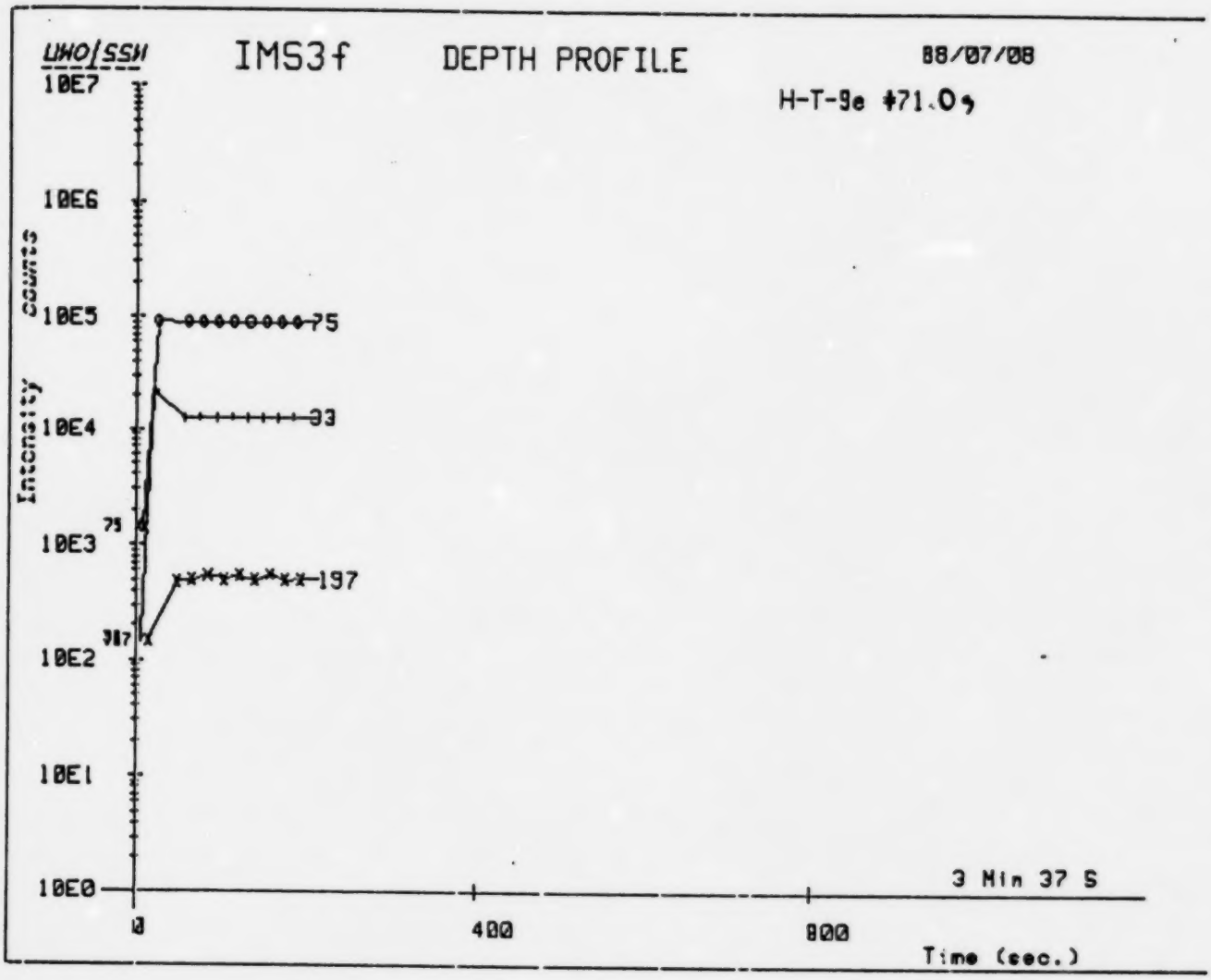
SAMPLE:H-T-9e #58 O
DATE:88/07/08
PRIMARY IONS : CESILM +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 373 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 1 2 3



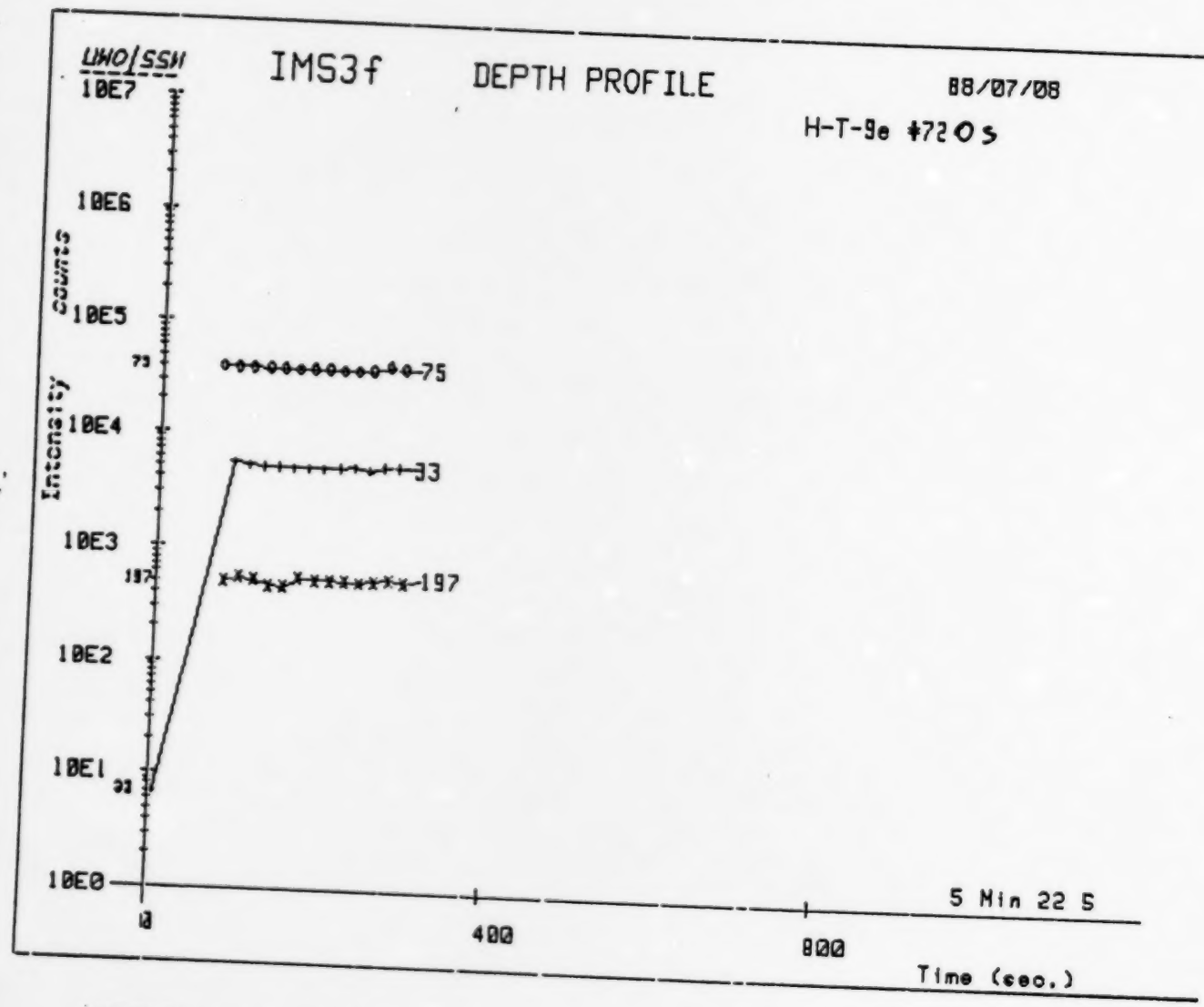
SAMPLE:H-T-9e #61O
DATE:88/07/08
PRIMARY IONS : CESILM +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 370 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3



SAMPLE:H-T-9e #71 09
DATE:88/07/08
PRIMARY IONS : CESILM +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 381 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE



SAMPLE:H-T-9e #72 O 5
DATE:88/07/08
PRIMARY IONS : CESILM +
SECONDARY IONS : -
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 375 NANO AMP
HIGH VOLTAGE :
156.65 DD.D
<ILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 1 2 3

Appendix A3

Assays and distribution of invisible gold in heavy and light fractions

ASSAYS OF HEAVY AND LIGHT FRACTIONS

	Mass Split	Au g/t	Au Distribution	As ppm	S %
Tailings	100	0.675 ±0.10	100	1040 ± 120	13.2 ± 1.2
Light fraction	79	0.15	17	120	0.65
Heavy fraction	21	2.67 (calc)	83	4500 (calc)	53 (calc)

DISTRIBUTION OF INVISIBLE GOLD IN HEAVY AND LIGHT FRACTIONS

	HEAVY FRACTION		LIGHT FRACTION	
	assay	distrib. %	assay	distrib. %
Assayed Au	2.67 (calc)	100.0	0.15	100.0
Invisible gold in arsenopyrite (30.2 ± 8.6 ppm) (0.87 % of heavy 0.025 % of light)	0.26 ±0.07	9.7 ±2.6	0.008 ±0.002	5.3 ±1.5
Invisible gold in pyrite (0.72 ± 0.38 ppm) (100 % of heavy 1.22 % of light)	0.72 ±0.38	26.9 ±14.2	0.009 ±0.005	6.0 ±3.1
Total invisible gold	0.98	36.6 +16.8	0.017	11.3 ± 4.6